Endovascular Treatment in Post-Surgical Cerebral Aneurysms

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Objective: The authors present the result of endovascular treatment in cases of residual or recurrent cerebral aneurysms after surgery.

Methods: 370 cases harboring 410 aneurysms underwent endovascular coil embolization over the past eight years. We selected 13 cases that underwent coil embolization in the post-surgical condition with residual or recurrent aneurysms. Radiologic and clinical data were reviewed to determine reasons of referral, outcomes, and technical problems of postsurgical endovascular treatment.

Results: The mean interval from surgery to endovascular treatment was 23 months (range 0 day to 121 months). The reasons of postsurgical endovascular treatment were: 1) incomplete clipping (n=6); 2) failed clipping (n=3); and 3) rehemorrhage (n=4). Among the 4 cases of rehemorrhage, 3 cases presented with recurrent aneurysms after clipping; one case had undergone aneurysm wrapping. At time of endovascular treatment three patients were classified as Hunt-Hess Grade 0, two Grade I, three Grade II, and five Grade III. In all 13 cases, treatments by endovascular coil embolization were successful, resulting in total or near total occlusion of aneurysms, with no procedure-related morbidity or mortality. Clinical outcome at time of the last clinical evaluation was; Glasgow Outcome Scale (GOS) 5 in ten patients, GOS 4 in one, and GOS 3 in one. Mean duration of follow-up was 17 months. No subarachnoid hemorrhage or aneurysm regrowth was noted during the follow-up period.

Conclusion: Endovascular coil embolization is a good alternative treatment modality in cases of postoperative residual or recurrent aneurysms.

KEY WORDS: Aneurysm · Endovascular therapy · Surgery.

Introduction

The aim in the treatment of intracranial aneurysms is complete closure of the aneurysmal lumen and exclusion of the lesion from the parent arterial circulation. Microsurgical clipping of aneurysms is a well-established means to achieve this aim. However, remnant aneurysms are found in 4 to 8% of patients on postoperative cerebral angiography3,7,14,22,25). In a series of cerebral aneurysm patients there is 1.5% chance of recurrence for completely clipped aneurysms and a 40% chance of enlargement of residual aneurysms over a 4-year period3). The risk of bleeding from incompletely clipped aneurysms is known to be 0.8 to 1.8% per year3,7). Repeated surgery for residual or recurrent aneurysms is an accepted treatment modality5,6,14,21), but frequently it is technologically difficult and accompanied by complications5,10,14). Moreover, some patients are reluctant to undergo repeated cranial surgery. Therefore, another treatment option, the endovascular treatment using detachable coils, may be required in this subset of patients with intracranial aneurysms. The authors report the efficacy and treatment results in a series of 13 cases that underwent intra-aneurysmal coil embolization after neurosurgical operations during the period from March 1996 to September 2003 at a single institution.

Materials and Methods

A total of 370 cases with 410 aneurysms were treated with endovascular detachable coil embolization during the period from March 1996 to December 2003. Among these we selected 13 cases that underwent coil embolization in the postsurgical condition, and retrospectively analyzed the clinical characteristics of these cases and the results of their endovascular treatment.

Five men and eight women were included in our series of postsurgical coil embolization. Mean age was 53 years (range 38 to 70 years) at time of intervention. The most frequent location of aneurysms in our series was the anterior communicating
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artery (ACoA) (n=6), followed by the internal carotid artery (ICA) (n=3), the posterior circulation (n=3), and the middle cerebral artery (MCA) (n=1). Three cases of clipping failure and one of incomplete clipping had undergone surgery at other hospitals. Clinical follow-up evaluation was possible in 12 cases. During the follow-up period, control angiography was performed in 2 cases, magnetic resonance (MR) angiography in 3 cases, and MR imaging in 3 cases.

Results

The reasons of referral for endovascular embolization in our series were: 1) incomplete aneurysm neck clipping, sometimes acknowledged by neurosurgeons, in 6 of 13 cases; 2) failure to clip the aneurysm neck in 3 cases, including 2 cases having undergone aneurysm wrapping; and 3) rebleeding after operation in 4 cases, including 3 cases after clipping and 1 case after wrapping. Angiography revealed recurrent aneurysms in cases presenting after prior clipping (Table 1). The mean interval between operation and intervention was 23 months (range 0 day to 121 months). In all 13 cases, endovascular embolizations using detachable coils were successful with preservation of parent arterial blood flow.

The clinical characteristics of the cases are summarized in Table 2. Pre-embolization Hunt-Hess grades of the patients were Grade 0 in 3 cases, Grade I in 2 cases, Grade II in 3 cases, and Grade III in 5 cases. The interval between embolization and the last follow-up varied from 2 to 70 months (mean 17 months). At time of the last clinical evaluation, the outcomes were Glasgow outcome scale (GOS) 5 in 10 cases, GOS 4 in 1, and GOS 3 in 1. One case (case 4) with a ruptured anterior communicating artery aneurysm was transferred immediately after intervention and lost to follow up. Follow-up imaging studies (n=7) revealed asymptomatic focal infarction of the right thalamus in one case (case 9) with a ruptured basilar top aneurysm. Otherwise, there was no evidence of aneurysmal recanalization or symptomatic procedure-related complication.

Emboloization in cases of incomplete aneurysm neck clipping

This group included 6 cases. The operators recognized the incompleteness of aneurysm neck clipping during surgery in 4 of the 6 cases, and referred these cases during the early postoperative period (mean 3.5 days after operation, range 0 to 8 days). Causes of incomplete clipping included incomplete neck exposure (Case 2), broad aneurysm neck and compromise of adjacent anterior choroidal artery (AChA) with complete neck clipping (Case 8), too small a bleb to apply the clip (Case 10), and clip slippage (Case 13). Control angiography revealed residual aneurysms, and coil embolization was performed immediately after angiography. In one case the surgeon performed partial neck clipping to produce a narrow aneurysmal neck for a following intervention (illustrative case, Fig. 1). One case (case 6) with a long interval between surgery and intervention had a ruptured ACoA aneurysm and an unruptured small basilar top aneurysm simultaneously. This case was referred for emboliz-

![Fig. 1. Surgical creation of aneurysmal neck. The patient (Case 8) initially presented with an unruptured aneurysm. The preoperative angiogram (A) shows a wide-neck aneurysm in the distal ICA. The 3D angiogram (B) shows the AChA arising just proximal to the aneurysm, and that the aneurysm neck incorporated part of the M1 segment of the MCA. After clipping the aneurysm with two fenestrated clips, the patient developed hemiplegia on the right side: angiography was performed immediately (C) and reveals no contrast filling of the aneurysm and the disappearance of the AChA. Re-operation was performed, the proximal clip was removed and the distal clip adjusted, creating a narrow aneurysm neck, and making the aneurysm suitable for endovascular coil embolization (D). Angiogram after the second operation (E) shows the residual aneurysm and patent flow through the AChA. Successful endovascular coil embolization with near complete occlusion of the aneurysm was achieved through the narrowed aneurysm neck (F).]

Table 1. Reasons for endovascular treatment in 13 postsurgical cases

<table>
<thead>
<tr>
<th>Reasons</th>
<th>No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incomplete clipping</td>
<td>6</td>
</tr>
<tr>
<td>Failed clipping</td>
<td>3</td>
</tr>
<tr>
<td>(Wrapping)</td>
<td>2</td>
</tr>
<tr>
<td>Rebleeding</td>
<td>4</td>
</tr>
<tr>
<td>(Post-clip)</td>
<td>(3)*</td>
</tr>
<tr>
<td>(Post-wrapping)</td>
<td>(1)*</td>
</tr>
</tbody>
</table>

*In these cases angiography showed recurrent aneurysms
tion of the latter after operation for the former aneurysm in another hospital. Cerebral angiography revealed a residual aneurysm in the ACoA and coil embolization was performed to occlude the ruptured and unruptured aneurysms at one session. The interval between operation and intervention was 53 days in this case.

Another case with a ruptured ACoA aneurysm (Case 10) had two blebs around the aneurysm (Fig. 2A, B). Postoperative angiography performed ten days after successful clipping of the aneurysm revealed an aneurysm of similar size on the ACoA (Fig. 2C). Three-dimensional(3D) angiography showed the clip-aneurysm relationship clearly. We found that the clip obliterated the anterior bleb but that the remaining posterior bleb had enlarged, with careful comparison of the preoperative and postoperative 3D angiograms. The next day coil embolization was performed for the posterior bleb and resulted in successful obliteration (Fig. 2D). The patient recovered to GOS 5.

In this group the follow-up interval was 18 months on average (range 2 to 70 months), except a case lost to follow up. The outcome was GOS 5 in all cases (n=5).

An Illustrative Case (Case 8)
A 65-year-old woman was admitted for the evaluation of a dull frontal headache that had developed one month previously. An intracranial aneurysm was suspected on MR imaging. Angiography revealed an aneurysm of the distal ICA (Fig. 1). The aneurysm arose just distal to the origin of the AChA and the size was measured 8.5mm in maximal diameter. It had a broad neck involving the bifurcation of the ICA and the proximal part of the MCA. At surgery the aneurysm was obliterated with two fenestrated clips. However, the patient was found hemiplegic when he recovered from the anesthesia. Angiography was performed immediately and revealed no visualization of the AChA, in addition to obliteration of the aneurysm. The patient underwent re-operation; the proximal clip of the two fenestrated clips was removed and the distal clip was relocated to make a

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**Table 2. Profiles of patients who underwent coil embolization after surgical treatment**

<table>
<thead>
<tr>
<th>No</th>
<th>Location</th>
<th>Modality</th>
<th>H–H</th>
<th>Reason for reference</th>
<th>Interval</th>
<th>Ocll</th>
<th>Fu (mo)</th>
<th>Outcome (GOS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1***</td>
<td>MCA</td>
<td>c</td>
<td>II</td>
<td>Rebleeding after clipping</td>
<td>na</td>
<td>nt</td>
<td>na</td>
<td>Fair (3)</td>
</tr>
<tr>
<td>2</td>
<td>PCoA</td>
<td>c</td>
<td>II</td>
<td>Complete clipping</td>
<td>0</td>
<td>t</td>
<td>70</td>
<td>Excellent (5)</td>
</tr>
<tr>
<td>3</td>
<td>ICA</td>
<td>f</td>
<td>III</td>
<td>Failed clipping</td>
<td>1 day</td>
<td>nt</td>
<td>55</td>
<td>Excellent (5)</td>
</tr>
<tr>
<td>4</td>
<td>ACoA</td>
<td>c</td>
<td>II</td>
<td>Complete clipping</td>
<td>8 days</td>
<td>nt</td>
<td>na</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>AICA</td>
<td>w</td>
<td>III</td>
<td>Rebleeding after wrapping</td>
<td>121 mo</td>
<td>t</td>
<td>7</td>
<td>Excellent (5)</td>
</tr>
<tr>
<td>8***</td>
<td>ICA</td>
<td>c</td>
<td>0</td>
<td>Complete clipping</td>
<td>1 days</td>
<td>nt</td>
<td>9</td>
<td>Excellent (5)</td>
</tr>
<tr>
<td>9</td>
<td>BA</td>
<td>c</td>
<td>I</td>
<td>Rebleeding after clipping</td>
<td>65 mo</td>
<td>nt</td>
<td>5</td>
<td>Excellent (5)</td>
</tr>
<tr>
<td>10</td>
<td>ACoA</td>
<td>c</td>
<td>II</td>
<td>Complete clipping</td>
<td>11 days</td>
<td>t</td>
<td>5</td>
<td>Excellent (5)</td>
</tr>
<tr>
<td>11</td>
<td>ACoA</td>
<td>w</td>
<td>0</td>
<td>Failed clipping (wrapping only)</td>
<td>75 days</td>
<td>nt</td>
<td>10</td>
<td>Excellent (5)</td>
</tr>
<tr>
<td>12</td>
<td>ACoA</td>
<td>w</td>
<td>0</td>
<td>Failed clipping (wrapping only)</td>
<td>16 mo</td>
<td>nt</td>
<td>9</td>
<td>Excellent (5)</td>
</tr>
<tr>
<td>13</td>
<td>PICA</td>
<td>c</td>
<td>II</td>
<td>Complete clipping</td>
<td>5 days</td>
<td>t</td>
<td>5</td>
<td>Excellent (5)</td>
</tr>
</tbody>
</table>

*Modality, modality of previous operation; H–H, Hunt and Hess grade; interval, interval between operation and coil embolization; ocll, degree of occlusion; MCA, middle cerebral artery; PCoA, posterior communicating artery; ICA, internal carotid artery; ACoA, anterior communicating artery; AICA, anterior inferior cerebellar artery; BA, basilar artery; PICA, posterior inferior cerebellar artery; na, not available data; c, clipping of aneurysm neck; t, failure of clipping; w, wrapping of aneurysm; mo, months; nt, near–total occlusion; t, total occlusion; Fu, duration of follow-up. GOS, Glasgow outcome scale. **The outcome was measured at time of discharge. ***In this case of wide neck ICA aneurysm, surgical clipping intentionally made aneurysmal neck narrowed.
narrow neck for the endovascular procedure to be followed (‘surgical creation of a aneurysmal neck’). After operation, the aneurysm was completely occluded by coil embolization. The patient was discharged without neurological deficit.

Embolicion in cases of failed aneurysm clipping
This group included 3 cases and all cases were referred from other hospitals. The locations were the ACoA in 2 cases and the ICA in one. In a case severe brain swelling was an obstacle to further dissection during the operation (Case 3). Wrapping had been performed in cases with ACoA aneurysms and specific surgical difficulties inhibiting successful clip application were not known. There was no difference in technical aspects, compared with those in cases undergoing coil embolization primarily. Successful coil embolization was possible using the double microcatheter technique in one case of ACoA aneurysm with a broad neck (Case 12). The intervals from operation to intervention were 1 day, 2.5 months, and 16 months and the follow-up intervals were 9, 10, and 55 months, respectively. At time of the last follow up outcome was GOS 5 in all.

Embolicion in cases presenting with postoperative rebleeding
Four of the 13 cases presented with rehemorrhage after previous successful operations. Locations of the aneurysms were the bifurcation of the MCA, the ACoA, the basilar bifurcation, and at the origin of the anterior inferior cerebellar artery (AICA). The first 3 cases had undergone direct aneurysm neck clipping and recurrent aneurysms were found at time of rebleeding, and the last case had undergone wrapping of the aneurysm. The state of the patients at time of rebleeding were Hunt-Hess Grade III in 3 cases, and Grade I in one. The mean interval between the previous operation and endovascular intervention was 87 months (range 65 to 121 months). The case with a wrapped AICA aneurysm (Case 5) had the longest interval. In two cases 3D angiography clearly demonstrated the relationships between clips and aneurysms. We observed an ACoA aneurysm of superior direction just behind a clip in a case (Case 7, Fig. 3A, B). In a case with a basilar top aneurysm (Case 9) the clip was found to be displaced by the superiorly projecting aneurysm, and a small bleb was observed in the posterior aspect of the aneurysm, indicating a rupture point (Fig. 3C, D). In this case with a broad-neck aneurysm encroaching both posterior cerebral arteries, successful embolization was possible with the right posterior cerebral artery protected by placing a second microcatheter. The mean follow-up interval was 8 months (range 5 to 12 months), except for a case lost from follow up. In a case with a basilar top aneurysm (Case 9) MR imaging showed a silent infarction in the right thalamus 1 month after embolization.

At the time of the last follow up outcome was GOS 5 in 2 cases, GOS 4 in 1, and GOS 3 in 1. The case with GOS 3 outcome (Case 1) had presented with hemiparesis at the time of rehemorrhage due to rupture of the clipped middle cerebral artery aneurysm. At time of discharge the neurological deficit from the rehemorrhage persisted after successful embolization of the aneurysm.

Discussion
The treatment goal for intracranial aneurysms is complete occlusion and thereby exclusion of them from the cerebral circulation. Microsurgical clipping is the care standard for intracranial aneurysms. However, residual aneurysms have been found in 4 to 8 % of patients by postoperative angiography.\(^{3,7,14,22,25}\). Besides, recurrence rates of aneurysms after clipping are reported to be from 1.5% to 2.9% in the long-term evaluation\(^{3,26}\). Suggested mechanisms for residual or recurrent aneurysms after surgery are: 1) technical or anatomical difficulties in surgical clipping, 2) slippage of aneurysm clips, and 3) regrowth from residual parts of aneurysms\(^{5,10,14}\). Our cases support this suggestion.

It is well-known that incomplete clipping may result in

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**Fig. 3.** 3D reconstruction images of rotational angiography in patients who presented with rebleeding after clipping. A and B: The patient (Case 7) presented with rehemorrhage 74 months after the successful clipping of an ACoA aneurysm. Three-dimensional angiographic images show the recurrent aneurysm in the posterior aspect of the clip between the clip and the A2 segment of the left anterior cerebral artery in anterior (A) and posterior (B) views. C and D: The patient (Case 9) rebled 65 months after the successful clipping of basilar top aneurysm. The aneurysm redeveloped between the clip and the top of the basilar artery, displacing the clip laterally in the anterior view (C). A bleb, a presumed rupture point, is well visualized in the posterior aspect in the lateral view (D).
recurrence of aneurysms or rebleeding\textsuperscript{3,4,6,13,19,23}, and the risk of rebleeding is estimated to be in the range of 0.8 to 1.8\% per year\textsuperscript{17}. In a late angiographic follow-up study of 102 cases harboring a total of 167 aneurysms after surgery\textsuperscript{14}, 2 cases (1.5\%) recurred among 135 aneurysms without residua. In addition, two of eight aneurysms with ‘dog-ear’ residua enlarged, and three of four aneurysms with broad-based residua enlarged. Eight de-novo aneurysms developed in 6 patients, giving an annual risk of 1.8\% per year. A history of multiple aneurysms was associated with de-novo aneurysm formation. According to a calculation based on hemodynamics, the difference between the pressure in incompletely clipped aneurysms and the systemic blood pressure is only 1 to 2 mmHg\textsuperscript{9}, and we may assume that there remains a significant risk of rebleeding in cases harboring residual aneurysms. Therefore, postoperative angiography and the long-term evaluation of patients with aneurysms is mandatory\textsuperscript{3,15}. At present we recommend control angiography in all patients who have undergone surgery for aneurysms to document the completeness of clipping.

Reoperation has been a solution for residual or recurrent aneurysms\textsuperscript{5,6,14,21}. However, reoperation may be technically difficult, often accompanied by complications\textsuperscript{5,10,14}, and a patient may refuse further surgery. Reoperation for aneurysm produces a poor result in 12 to 16\% of cases\textsuperscript{1,10,14}. There are several reasons for these poor results\textsuperscript{10}. First, the presence of residual aneurysm reflects technical or anatomical difficulties of the prior operation. Second, adhesion may have been too severe for adequate dissection around the aneurysm, especially in cases with long intervals between initial and repeated operations, raising the risk of intraoperative aneurysm rupture. Third, the clip applied during the previous surgery can be an obstacle at subsequent operation; often it may be difficult or impossible to remove the clip when it is necessary, and aneurysm rupture and bleeding may occur during clip mobilization.

Endovascular treatment can be an appropriate therapeutic modality in these circumstances\textsuperscript{1,2,9,16,18,20,24}. Fraser et al.\textsuperscript{9} first reported the results of coil embolization in cases of incompletely clipped aneurysms. Rabinstein et al.\textsuperscript{20} performed coil embolization in 21 patients harboring postoperative residual aneurysms. Complete occlusion of the aneurysms was achieved in 81\% without a procedure-related complication. Hoh et al.\textsuperscript{15} reported treatment outcomes in 25 cases of residual or recurrent aneurysms. The incidence of complications amounted to 16\% in the surgically treated group. Therefore, they recommended endovascular treatment in cases with aneurysms of the posterior circulation or lesions larger than 10mm.

Endovascular management of previously clipped aneurysms poses some technical difficulties\textsuperscript{18}. First, visualization of the aneurysm neck may be difficult, because the clip lies across it. When the clip hides the neck, positioning of the microcatheter and the coils becomes difficult under fluoroscopic control. Second, the aneurysm neck crossed by the clip is rigid. During coil placement the rigid wall may push the coils back. Besides, the shape of residual aneurysm is frequently triangular or quadrangular and the depth is shallow. This makes the stabilization of coils difficult or impossible. In cases of tiny dog-ear residue further endovascular treatment will not be feasible.

We encountered similar technical difficulties during endovascular treatment of 10 cases with previously clipped aneurysms. The clip frequently concealed part of aneurysm, and as a result, it was difficult to define the neck or dome of the aneurysm. In these circumstances, rotational angiography and 3D reconstruction, performed in 8 cases, provided crucial anatomical information regarding the aneurysms and related clips. In addition to the clip-aneurysm relationships, this also allowed us to understand the configurations of aneurysms and their relationships with the parent artery, and to decide adequate working angles easily (Figs. 1, 2, 3).

We obtained satisfactory angiographic results and clinical outcomes without symptomatic procedure-related complications, except in one case with an asymptomatic small thalamic infarction. Occasionally, severe calcification of aneurysm neck, severe tortuosity of vessels around aneurysms, and an inaccessible aneurysmal neck precludes direct clipping. These lesions can be safely obliterated by endovascular coil embolization after the creation of a narrow aneurysm neck by partial neck clipping\textsuperscript{1,16}, as shown in the illustrative case. Currently a variety of methods, using 3D or complex coils, balloons, and stents, are being applied for broad-neck aneurysms. Coil embolization after partial clipping might be an alternative method for the occlusion of broad-neck aneurysms in cases of attempted surgery\textsuperscript{1,16}.

Endovascular coil embolization is already widely accepted as a standard tool for treatment of intracranial aneurysms. Satisfactory results can be achieved with coil embolization if adequate cases are selected\textsuperscript{12,17}.

**Conclusion**

Endovascular treatment can be a good alternative to reoperation and its feasibility should be sought in cases of residual and recurrent intracranial aneurysms found after surgery. Postoperative angiography seems to be required to ensure the completeness of clipping and long-term follow-up may be necessary in cases of cerebral aneurysm despite successful treatment.
References


